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FACTORS INFLUENCING URBAN RESIDENTIAL WATER CONSUMPTION IN BENGALURU

Kavya Shree K[1] and Krishna Raj[2]

Abstract

Bengaluru city faces severe water crisis, with dying sources and inefficient use of drinking water. The sources of water important to understand the quantity of water consumed. Usually, the demand for water is more elastic with respect to public piped water supply, as the pricing is often subsidised due to the fact that it is a social good rather than an economic good. Identifying the factors influencing water consumption in Bengaluru city is the key to offer suitable policies for efficient water utilisation and management. In this study, urban residential water consumption and its influencing factors are identified and analysed by using the Ordinary Least Square method. The results show that the various variables considered are statistically significant, which affect residential water consumption. The variables that influence water consumption are the number of dependents in a family, its location, size of the house, different sources of water, water price and education of the consumers.

Keywords: Water, Factors, Bengaluru, residential domestic water, OLS

Introduction

Water is a vital resource for the existence of living species. Not just the availability of water but its availability at a certain prescribed quality and quantity cannot be over emphasised. It is the paramount task of the regulating authority to ensure maximum efficiency in managing the resource with as much equity as possible in distributing it. There is ample scientific evidence now to show that the pace of economic growth is not in proportion to the pace at which resources are getting replenished. Ranganathan (2014) in his study on the water scarcity issue of Bengaluru makes a note of the rapid transformation of the periphery of Bengaluru into globally connected technology parks ever since the process of liberalisation began in the 1990s. The increasing boundary of the city along with its tag as the global information technology hub have led to changes in the existing infrastructure to meet the pre-defined 'global standards of cities' leading to an increased demand for water as per Danker (2010). McDonald R *et al* (2011) in their paper mention that amongst the many environmental challenges which the cities face due to their rapid economic growth, the most apparent and widespread challenge is that of water scarcity. There are many studies that have estimated the per capita water supplied to Bengaluru city and have concluded that it is less than the WHO supply norm of 150 litres per capita per day (lpcd) and even the Central Public Health and Environmental Engineering Organisation (CPHEEO) supply norm of 135 lpcd. Some prominent estimations are Metha *et al* (2013) have estimated that in rapidly expanding areas of the city, the supply is 40 lpcd on an average, while it is 60-70 lpcd in slowly expanding areas of the city. Another study by Krishna Raj (2013) estimates the supply to be 75 lpcd on an average. It is thus clear that the supply of water to the city is less than the norm of 150 or 135 lpcd. With respect to Bengaluru's ground water, many studies (Merchant *et al*, 2014, K V Raju *et al*, 2008,

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Central Ground Water Board Report 2008, Centre for Science and Environment, 2010, Shakya *et al*, 2019) point to the fast depleting ground water table as the indicator for the increasing demand for water and hence the water scarcity challenge in the cities. The quantitative assessment of exploitation of ground water resource is given by K C Subhash Chandra (2012) where he mentions the city's ground water draft is estimated at 12450 ham/year while the ground water recharge from various sources is 3290 ham/year. This leads to the withdrawal being nearly four times more than the annual ground water recharge. In such situations, it becomes imperative to understand the water consumption pattern and most importantly the factors which affect water consumption in residential households, if the objective is to achieve water security and sustainability. Apart from the water resource depleting at a fast pace, it is also a known fact that water has competing uses, not only for domestic needs such as drinking, cooking and non-potable purposes such as washing vessels, clothes etc. but also for agriculture and industries. To ensure that the distribution of water is in the most equitable manner, it becomes important to identify the factors which influence the consumption of the resource in different competing sectors. It must also be noted that as argued by Damilola & Temitope (2014) water consumption patterns significantly differ within each competing sector; in the case of household water consumption, significant differences are seen in the water consumption pattern among rural households and urban households, with different culture settings and also among different time periods such as summer and winter. For sustainable and integrated management of the depleting resource, it becomes imperative to understand, allocate and identify use behaviour under competing sectors. Among the many competing water users, residential water consumption is the most important, which needs additional focus from the authority since safe clean water is imperative for human survival and economic development.

The peri-urbanisation process is another crucial observation made by Balooni, K & Venkatachalam, L (2016) in the Indian urbanisation context, which puts additional stress on water. It is a process wherein the rural areas are becoming urban in nature. This trend exerts an additional stress on the available water resource, especially when the water uses become varied and conflicting in nature. Peri-urbanisation increases the need for infrastructural and real estate developments, which often require large quantities of water. This changing process not only leads to increased water usage, but also increases the transaction costs for the water which gets supplied to cities.

The above discussion highlights that there is a problem of water scarcity as well as unsustainability in water source for urban areas, especially in the context of Bengaluru city. No doubt it is a daunting and a challenging task for the institutions to achieve efficiency coupled with equity and sustainability in the provision of water when the water source is dwindling. But it highlights a crucial problem - If there is a situation where people are not receiving the minimum stipulated water quantity in good quality, then it hints at an institutional failure. So, a key policy question arises: how to create appropriate institutions or initiate reforms in existing institutions to ensure there are both incentives as well as disincentives created which can influence the behaviour of all the relevant stakeholders responsible for efficient, equitable and integrated water management. To explore the above question, it becomes imperative to understand the factors which influence water consumption in Bengaluru city, and if they have been considered while making policy decisions.

Against this background, this paper attempts to examine in detail the behaviour of various identified variables on residential water consumption in Bengaluru. The analysis is restricted to urban settings of Bengaluru since the quantity of water demanded and consumed is relatively more when compared to rural settings. The following analysis will help policy makers to identify the significant variables and acknowledge the intensity of their effect on residential water consumption. It also facilitates effective policy making by targeting those variables which significantly influence water consumption and thereby achieve reduction in water demand owing to the scarcity of the resource.

The factors which influence residential water consumption are varied and complex. It must be noted as argued by Linneck (2015) that often the end users, especially residential, will not be aware of the treatment processes, infrastructure and delivery of potable water. In such cases, we need to identify which factors influence their consumption behaviour, more importantly behavioural factors such as their knowledge about the price per litre of water consumed. If reduction in consumption needs to be achieved, then consideration of social, psychological and cultural factors along with infrastructural, economic and household characteristics becomes imperative. Also, as identified by Klein *et al* (2006), water acts both as an input and also for final consumption. They also highlight two approaches - 'water requirements approach' and 'economics approach' - for estimating water demand for competing uses. The former estimates using per capita water demand multiplied by projected population to derive the future water demand, while the latter estimates the household water consumption based on consumer behavioural variables and then extends the analysis to all households. Through a literature review, the most significant factors influencing residential water consumption are identified and analysed in the following paper.

Study Area

The present study is focussed on the Bengaluru Urban district due to the impending water crisis the city is headed towards as reported by the supreme policy advisor to the government, NITI Aayog in their report in 2016. This was also corroborated by another study by Sudhir (2013) forecasting that the city is likely going to run out of water in the coming decades. If historically observed, then Bengaluru does not have a water source of its own. The founders of the city then used large tanks attached to a long running water inlet surrounding the city called the Raja Kaluve. F S Saidoddin *et al* (2011) in their study emphasise that the current state of water crisis the city is undergoing is because of the lack of the understanding of the city's water network. They also observe that the importance of the water network for the city became ignored with the city's expanding development leading towards increased demand for land along with changes in lifestyle.

The city is heavily rain fed and receives on an average 929 mm of rainfall as highlighted by the study done by Ammanaghatta Rudrappa Shivakumar in 2018 by taking a 100 year average rainfall data. As of 2011, the population of the city was 96.22 lakh of which 90.94 per cent resided in urban areas. The city is expanding beyond its carrying capacity, which in turn is putting a stress on the limited resources available for the city to thrive. When it comes to water, then the city is chronically short of the required quantity, and especially during the summer season, the pressure on the limited available water resource can be noticed by the exorbitant price charged by private tankers. The area of the city is

800 square kilometers. The responsibility of providing amenities falls on the Bruhat Bangalore Mahanagara Palike (BBMP). With respect to piped water supply and sanitation for the city, the onus falls on Bengaluru Water Supply and Sanitation Board (BWSSB). But it must be noted that there is a prevalence of alternative sources of water in Bengaluru such as private water tankers, bottled water, open wells and private borewells. This study is restricted to piped water supply supplied by BWSSB to urban households in Bengaluru. Also, the study focusses only on surface water, though there is a decent amount of usage of ground water by the households in Bengaluru.

Review of Literature

Studies on water demand management using water consumption as a proxy variable for water demand identify two types of categories of variables – one set which is controlled by water service utilities and the other which influences water consumption but is not directly controlled by the water supply utilities. A majority of the studies use utility controlled variables which do not focus just on the price but also on non-utility controlled or 'environmental variables' such as quantity restrictions, retrofits, awareness campaigns etc. This study also uses utility controlled variables to identify the statistically significant factors influencing water consumption behaviour among residential households in the Bengaluru Urban district.

Foster Jr and Beattie (1979) estimated the urban demand for water in the United States using the central tendency estimation and elasticity approach. The factors considered in their study include the average water price, median household income, precipitation and average number of residents. Another study by Platek and Lundeen (1980) using the linear regression method studied the factors influencing residential water demand in Big Sioux River Basin, USA and observed that the average price of the first 1000 cubic feet of water and income to be the statistically significant variables among the variables included in the study such as marginal price of water, average per capita income, number of persons, average price of first 1000 cubic feet of water and rainfall deficiency.

A similar study done by Graeme Dandy *et al* in 1997 to estimate residential water demand in South Australia using the static and dynamic regression model identified the statistically significant variables to be property value and household size. They also estimated the marginal price of water elasticity to be in the range of -0.6 to -0.8.

In 2003, an interesting study by Hassan I. Al-Mohannadi *et al* studied the significance of people's perceptions and attitudes towards water and its conservation in Qatar. They used frequency, cross tab and chi square in their study to understand the perceptions of people. Amongst the many variables considered, the influential variables identified were awareness campaigns, legal restrictions and water tariffs.

The relationship between urbanisation and water consumption was studied by Elena Domene and David Sauri in 2006. The study highlighted the influential variables affecting water consumption in Barcelona and the variables observed using the linear regression model are housing type, garden necessities, household size, presence of swimming pool, income and consumer behaviour towards water conservation practices. The study also calculated the Consumer Behaviour Index with respect to urban residential water consumption.

Elizabeth Wentz and Patricia Gober (2013) in their study identifying factors influencing multifamily water consumption in Arizona used the Ordinary Least Square method and Geographically Weighted Regression (GWR) to identify the statistically significant variables to be household size, presence of pools, mesic landscaping style, lot size, and the influence of neighbours.

A number of studies have highlighted the significant variables affecting residential water consumption to be income and water price among other variables (Platek and Lundeen (1980), Elena Domene and David Sauri (2006) Hugh March *et al* (2009), R. Quentin Grafton *et al* (2011)). Apart from the quite obvious variables such as water price and income, some of the other statistically significant variables emerging out of the literature review with respect to residential water consumption is household size, number of dependents and awareness about price of water (Graeme Dandy *et al* (1997), Elena Domene and David Sauri (2006), Elizabeth Wentz *et al* (2013), Elizabeth Ramsey *et al* (2017).

Apart from the studies mentioned above, a summary of other studies reviewed before choosing the variables for this study is made in the table 1 below:

Table 1: Literature Summary on Factors Influencing Water Consumption

Name of the Author/s	Year	Dependent Variable	Independent Variable
Omar S Abu Rizaiza	1991	Annual usage per household	Average price; Household size; Education of household's head; Temperature
Reitveld (Rietveld *et al*, 2000)	2000	Monthly water consumption	Household size; Monthly income
Whittington (Whittington, 2002)	2002	Monthly water consumption	Average price; No of women; Monthly income; Mean of 2 adults educated year; Education level of the respondent; Water collection time; Distance to water sources; Storage tank; Water quality and taste
Basani (Basani *et al*, 2004)	2004	Monthly water consumption	Marginal price; Connection fee; Household size; Household expenditure; Education of household's head; Access to electricity; Ethnicity
Strand (Strand & Walker, 2005)	2005	Monthly water consumption	Average price; Marginal price; No of adults & children; Monthly income; Value of house
Nam (Nam & Son, 2005)	2005	Monthly water consumption	No of adults & children; Education level of the respondent; Household size; Water quality and taste
Rauf (Rauf & Siddiqi, 2008)	2008	Monthly water consumption	Marginal price; Ratio of AP/MP; Household size; Value of the house; Size of the property; Temperature
Nauges (Céline Nauges & van den Berg, 2009)	2009	Monthly water consumption	Household size; Monthly income; Education of household's head; size of the property; Access to electricity; Water quality & taste
Aminou Arouna *et al* (Arouna & Dabbert, 2010)	2009	Purchased water demand	Household size, Household size squared, Gender ratio of children to adults, Expenditure, Population, Occupation, Education, Time for fetching water in rainy season, Access to public well, Access to public pump, Access to own opened well, Access to other opened well, Price
Liangxin Fan *et al* (Fan *et al*, 2013)	2013	Domestic water consumption	Water supply pattern, Water price, Age of the household head, Educational attainment of the head, Household head sex, No of children, Household income, Net family size (excludes members residing outside for more than 8 months), Vegetable garden area, Yard area, Livestock number, Washing machine, Solar water heaters
Fayyaz A *et al* (Hussien *et al*, 2016)	2016	Per capita water consumption	Household size, Number of children (<15 years), Number of adult male members (15–65 years), Number of adult female members (15–65 years), Number of elders (>65 years), Household type, Total built-up area of all floors, Garden area per household, Number of rooms in the household, Number of floors in the household, Monthly family income/household
Rubén Alejandro Villar Navascués *et al* (Villar-Navascués & Pérez-Morales, 2018)	2017	Domestic water consumption	Household income, Water price, Household size, Type of housing

Literature suggests the methodology used in studies which use cross section data to estimate factors influencing water consumption is Ordinary Least Square method.

From the above table, the most commonly used variables identified are: Water price, Household income, Type of housing, Household size, Number of taps, Garden area, Number of children, Metering, Climate, Rainfall, Temperature, Vegetation area etc.

Research Methodology

This section discusses the research frame and technique used for identifying factors which affect residential domestic water consumption significantly. The findings of the study are based on primary survey data collected from Bengaluru Urban households using the structured questionnaire method. The questionnaire was elaborate to cover not just the mentioned variables for the study but also other areas such as water conservation practices, policy options for water conservation and so on. A pilot study of 40 households was conducted in Banashankari III Stage area to identify the loopholes of the questionnaire. The questionnaire was accordingly corrected and then data was collected for the entire Bengaluru Urban. The total sample needed with a population of 96.22 lakh as per Census 2011 and with 95 per cent confidence level is 384. However, data for 500 households were collected. The collected data was sorted, cleaned and then entered into MS Excel for analysis. The coefficients of variables under the study were statistically estimated and hence concluded on the relation and its intensity on the water consumption variable.

Data Collection Methodology

To establish the relationship between various variables considered for study on the water consumption variable, primary data was collected from Bengaluru Urban. The total sample considered for the study was from Bengaluru Urban and domestic households only. Stratified Random Sampling technique was used for data collection. To ensure representation from the entire study area, it was divided into stratas. Each stratum represented one of the 8 BWSSB zones. Proportionate stratified sampling technique was further used whereby a minimum of 40 households was visited in each zone randomly to collect the data. For Bengaluru’s population of 96.22 lakh with confidence interval of 95 per cent, the determined sample size is 384. However, the raw data collected was from 500 households. Post data cleaning and sorting, the data, that which could be used for analysis, was 457. Hence the econometric model is estimated with the sample size of 457.

Empirical Model

The empirical model for testing the above hypothesis is elaborated below:

For the analysis, the multiple regression model was used. Since the data collected was cross sectional, literature suggests Ordinary Least Square method to be the most apt to quantity the relationship dependent and independent variables.

The functional form of the OLS model is as follows:

$$y_i = \beta_o + \beta_1 X_{1i} + \cdots + \beta_k X_{ki} + i$$

Where Y_i is the dependent variable; β_0 is the constant; $\beta_{1...k}$ are the coefficients of the explanatory variables and i is the error term.

The model used in the present study is specified as follows:

Household water consumption = f (Household size, number of dependents, number of working members, location, knowledge about water price, pricing model, education, source of water)

The model is estimated and is also checked for assumptions according to the Gauss Markov theorem which is elaborated in the Results and Discussion section below. The results of the model are discussed in detail in the Results and Discussion section below.

In the urban context, the most important variable to be analysed to achieve the objective of water security is domestic water consumption. The explanatory variables analysed to understand the behaviour of domestic water consumption are: Litres of water consumed as per the water bill, Income, Education, Non-price variables such as the socio-demographic variables which focus on the built-up area of the residential property, population density, number of taps etc. A detailed list of the variables used for the study are mentioned in the table below:

Table 2: List of Variables used in the OLS Model

Dependent Variable	**Explanatory Variables**	**Explanatory Variables Description**
Monthly Water Consumption (in litres as per the water bill)	**No of dependents**	No of people falling in the age group of (0-14) and (60+)
	No of Working Members	Dummy variable
	Locality	Zone wise. There are eight zones. Each zone is represented by a dummy variable
		Dummy variable Name
	South	zone 1_dummy
	East	zone 2_dummy
	West	zone 3_dummy
	Bommanahalli	zone 4_dummy
	Yelahanka	zone 5_dummy
	RR Nagar	Reference Variable
	Dasarahalli	zone 7_dummy
	Area of the House	In square feet
	Source of Water Supply Public Source (BWWSB) or Other. In case of 'Other' source the below mentioned combinations are considered: Private water supply (private borewell, private water tanker, private open well, bottled water, others) Piped water supply Piped Water Supply + Private Water Tanker Piped Water Supply + Private Water Tanker +Private Borewell Piped Water Supply +Bottled Water	dummy variable
	Knowledge about price of water	Dummy Variable
	Education: **Primary and Higher Education** **University and Above**	Dummy Variable

The reason for not considering water price in the model is the fact that it may lead to spurious regression since water price data is collected through the primary survey using the proxy variable – the latest BWSSB water bill amount paid by the respondent. Data on the quantity of water consumed by the respondent which is the dependent variable in the model is also collected from the latest water bill. The effect of water price on water consumption can be estimated only if there is a change in the water price fixed by the authority and when the data can capture the quantity consumed before and after the price change. But this study data has this limitation. Hence the water price variable is dropped from the model.

Variables

Residential water use and water consumption has been attributed to a number of factors as identified by the literature. However, for Bengaluru, there exists very limited literature on identifying the factors influencing residential water consumption. The theoretical understanding of the variables considered and its relation to residential water consumption for this study are explained below. The influence of these variables on residential domestic water consumption is being assessed. The dependent variable considered for the model is water consumption in litres, data for which is procured from the April 2018 BWSSB water bill of the respondents. The explanatory variables considered for the study are as follows:

Number of Dependents

Since water has no substitutes, it is often regarded that its demand is highly inelastic. The inelasticity of water demand can also be attributed to the number of dependents in a household. The size of the family and water demand hold an increasing positive relationship i.e. higher the number of family members, higher is the quantity of water consumption. Several studies (Froukh, 2001), (Keshavarzi *et al*, 2006), (Arouna & Dabbert, 2010), (Totouom *et al*, 2018) have proved there exists a relationship between household size and composition and water use. Totouom finds that the number of female members in the household affects the quantity and quality of water consumed also. He identifies that often the households with more female members consume more quantity of water when compared to families with only male members since in most developing countries, the task of fetching water falls on the female members. Apart from the number of members, it also becomes important to identify the number of dependents, especially children and the elderly members in a household since as the number of dependents increases, the water consumption also increases. For example Lyman (1992) finds that adding one more child to a house increases the water usage by 1.4 times that of an adult. Hence categorising the household members according to age slabs becomes essential to identify the impact of the number of dependents on water consumption.

Locality

As Bengaluru's water supply process is one of the most expensive in India, it becomes important to consider and analyse whether the location of the household has an impact on the water consumption. The reasoning behind considering this variable is the differences that exist among locations within Bengaluru. The difference could be due to the population of the locality, income capacity, distance from the main water source, historical reasons such as the existance of a better pipe network etc. A study done by Mohan *et al* noted that there exists a variation in the water consumption quantity based on the locality of the household. They identified that the South Zone of Bengaluru consumes the maximum quantity of water supplied by the BWSSB. The impact of the variable-distance from water source on water consumption has also been extensively studied by various studies such as UNFPA Report 2002 (*UNFPA Report 2002*, n.d.), which estimated that in developing countries on an average, 6 kilometres is the distance covered by female members to collect water. The GOK 2006 report also identifies that especially the girl child is often denied education and other female members the opportunity to earn due to the time and effort needed to collect water daily. Many more studies (Mu *et al*, 1990) (Madanat & Humplick, 1993), (Hindman Persson, 2001), (Howard & Jamie Bartram, n.d.), (Reniko *et al*, 2020), (Dar & Khan, 2011), (Mason, 2012), (Bartlett, 2003), (Damilola & Temitope, 2014) have all identified that the distance to fetch water becomes an important determinant to assess the water consumption pattern among domestic households. In the current study, the location variable is subdivided into 7 dummy variables, each representing zones as per the BWSSB distribution categorisation.

Area of the Household

It is obvious to hypothesise that the area of the household will have a positive relation with water consumption i.e. bigger the house in area, larger will be the water consumption. However, the relationship is not obvious with respect to literature. Studies (Billings & Day, 1989), (Lyman, 1992), (Deoreo & Mayer, 1999), (Renwick & Green, 2000), (Cavanagh *et al*, 2002) have found that there exists a positive relation with household size and water consumption. Cavanagh *et al* (2002) have concluded that in urban areas of US and Canada, for every additional 1000 square feet, the water demand increased by 13-15 per cent. Renwick & Green (2000) observed that for every 10 per cent increase in the area, the water demand increases by 2.7 per cent. Though the above studies find a positive relationship, studies done by Howe & Linaweaver (1967) and Hewitt & Hanemann (1995) find the variable not to be statistically significant. Many studies have also found that since household size is much similar to property value, they have used a proxy variable - Number of taps - to study the effect of household size on water demand. In this study, the data is collected on both household area in square feet unit and also number of taps in the house. Both the variables were studied and it was found that larger the square feet of the house, large is the number of taps in the house. Hence household area in square feet unit has been included in the estimation model.

Source of Water Supply

The source of water becomes an important factor to understand the quantity of water consumed. This is because the demand for water is more elastic with respect to public piped water supply as the pricing is often subsidised due to the nature of the good i.e. water is considered to be a social good rather than an economic good. But what if the household is not connected to public piped water supply? Another reasoning behind identifying the water source is if the household is not connected to piped water supply then the members must invest extra time and effort to collect water for consumption. If the source of water is far off, then obviously water is used with more consciousness and hence there is less wastage.

Similarly, if the cost of water is more, for example if it is a private water source i.e either from private water tankers or bottled water, then the price for water paid will be higher than the public water supply price. This ensures efficient usage of water. Hence it becomes imperative to identify the source of water to understand the water consumption in the household. Many studies have been done to estimate the relationship of the source of water on water consumption/demand (Acharya & Barbier, 2002), (Céline Nauges & Strand, 2007), (Basani *et al*, 2004), (Cheesman *et al*, 2008), (Céline Nauges & van den Berg, 2009), (Basani *et al*, 2008) and (Céline Nauges, n.d.), (Coulibaly & Burn, 2004)estimated the water demand from non-public sources alone while (Acharya & Barbier, 2002) estimated the water demand purchased from private water vendors in Nigeria. Cheesman *et al* (2008) on the other hand estimated the water demand from two different sources – one from municipal water and the other from household private well. Nauges and van Den Berg similarly studied the water demand pattern and estimated the same with respect to Sri Lanka wherein they estimated two water demands separately for piped and non-piped water sources. Based on the data collected, the present study subdivides the source of water supply into five categories and estimates their impact on household water consumption. The categories are: Private Water Supply (private borewell, private water tanker, private open well, bottled water, others); Public Piped Water Supply from BWSSB; BWSSB Piped Water Supply + Private Water Tanker; Piped Water Supply + Private Water Tanker +Private Borewell; Piped Water Supply +Bottled Water. For the model, however, dummy variables are used to represent the source of water – public piped water supply and Others category which includes all the categories of water source mentioned above.

Knowledge about Price of Water

To understand the effect of consumer behaviour on any product or service, it is important to understand the attributes which the consumer values the most. One of the most important attributes is the knowledge about the price of the commodity or service. Often in the case of public goods, the price is highly subsidised for the benefit of the lower income section of the society. In such cases, consumers are unaware of the market price of the good they are consuming and hence the extent of subsidy they receive. This imperfect knowledge has a gross impact on the water consumption habits of people. To assess this 'knowledge about price of water,' a variable has been included, the estimation model. In literature, a proxy variable for knowledge about water consumption and water price, which is 'awareness campaigns', is being assessed. Some of the studies include Dziegielewski (2003), Renwick and Green (2000), Renwick and Green (2003), Butler & Memon (2005) and Sydney Water Annual Report 2010 (2010). The Renwick and Green study in 2000 found that a public information campaign strategy reduced residential water consumption by 8% through influencing people's water use behaviours. Another study by Butler and Memon (2006) noted that public information and education programmes are crucial for the success of demand-side management, particularly in developing countries. Dziegielewski *et al* (1993) show that water use was reduced by 26% through a four-year education programme in California. Sydney's water conservation initiatives for the period 2009-2010 have saved about 116.7 GigaLitres (1GL = one billion litres) of water and especially education programme for households helped to reduce over 17.2 GL of residential water use each year. (Sydney Water Annual Report 2010 (2010).

Education

Not much literature is available which includes education as a variable to assess its impact on water demand. There are two perspectives in which education as a variable is included in this study. Firstly, it can be regarded that education brings about a behavioural change among the individuals. It strongly influences individual perceptions towards water conservation and water wastage. The relationship between the two variables in this perspective can be foreseen as negatively correlated i.e. as the individual increases his educational attainment in the form of formal degrees, his attitude towards water conservation and reduction of water wastage will be more intense. Another perspective is where education can also lead to increased consumption of water. The reasoning for the same is as follows: Higher the education an individual attains, the probability of securing a high income job also increases. An increase in the income of the individual can also result in a relatively less proportion of his/her income being spent on water. This may lead to conspicuous consumption of water, thereby increasing the total water consumption of such households. In such a situation, the relationship between the two variables can be regarded as positive i.e. higher the education attainment, higher is the total quantity of water consumed. Also, he becomes aware of the consequences of acute water shortage. Hence, he will demand less water. In the current study, the education variable is divided into two sub variables - Primary and Higher Education Level as one variable and University and above as another variable. Dummy variables representing the same have been included in the model.

Pricing Model

Water price is an economic instrument which influences consumption quantity inversely i.e. as the water price increases, water consumption must reduce. But this also depends on a crucial concept, which is elasticity of demand. If the usage of water is highly inelastic, then the price effect is nullified. On the other hand, if usage is highly elastic, then water consumption becomes keenly sensitive to changes in price. This works if the commodity is a normal good. The question again arises if water is a normal good. Water is considered more of a social good rather than a normal economic good (Hanemann, 2005). The implication of this characteristic is that the social component of the good is given more importance than the economic principles behind pricing it. The pricing model can be of many types. The most commonly practiced are Full Cost Pricing, Marginal Pricing model, Average Pricing model and Increasing Block Tariff (IBT) model. The most economic model of pricing is the Marginal Pricing model wherein the consumer pays the price which is equivalent to the cost of producing one extra unit of water. But the most commonly practiced model is the IBT model wherein blocks are determined on the basis of increasing water quantity consumption. Higher the block, higher is the tariff per unit of water fixed. This ensures equity to a certain extent, but it does not guarantee an efficient and sustainable way of supplying water to consumers.

Numerous studies have been made to identify the influence of water pricing on water consumption. Some of them include Agthe & Billings (2002), Arbués *et al* (2003), Inman & Jeffrey (2006), Corbello March & Sauri (2009), Russell & Fielding, (2010) and Willis *et al*, (2011). An interesting policy suggestion by Arbués *et al* (2003) is that the water pricing need not follow one pricing model throughout. They suggest seasonal price or peak price tariffs during high demand seasons to ensure efficient water usage and control water wastage.

Table 3: Studies to Estimate Price Elasticity in Various Countries

Author	Year	Methodology	Findings
Howe and Linaweaver (Howe & Linaweaver, 1967)	1967	Average Price (AP) model (USA)	Price Elasticity (E_d) : -0.23
Gibbs (Gibbs, 1978)	1978	Linear Model (Florida)	E_d : -0.15
Billings (Billings, 1982)	1982	Linear Log Model (Arizona)	E_d :-0.66 (MP); -056 (Dynamic model)
Chicoine and Ramamurthy (Chicoine & Ramamurthy, 1986)	1986	Linear (Illinois)	E_d: -0.6
Renwick, Green, McCorkle (Renwick & Archibald, 1998)	1998	Logarithmic (California)	E_d: -0.16
Nauges and Thomas (Celine Nauges & Thomas, 2000)	2000	Linear (France)	E_d: -0.22
Ayadi, Krishnakura, Matoussi (Ayadi *et al*, 2002)	2002	Logarithmic (Tunisia)	E_d: -0.17
Inman & Jeffrey (Inman & Jeffrey, 2006)	2006	OLS	Europe: -0.28 Eastern United States: -0.005 Western United States: -0.17 Australia: between -0.60 to – 0.80

These are numerous studies which quantify the impact of price on water consumption. Though there was an attempt to include the water price variable, it could not be included as a variable in the current study since the water price depicted by water tariff has remained the same since 2012. The price elasticity of water can be quantified only if the data accounts for changes in price and hence a change in the water quantity consumed. But for the current study, the data collected is stationary i.e. it is collected at one particular time point and hence suffers from the limitation of not including the water price variable in the study. Data was however collected to understand the preference for the pricing system - average pricing or marginal pricing system - from the respondents which indirectly highlights the water conservation consciousness of the respondent.

Results and Discussion

This section elaborates on the results of the analysis done using STATA software. The primary data was keyed into STATA and then the OLS model was run. The results were tested for linearity, outliers, multicollinearity and heteroscedasticity. The test results are discussed in section 1.10.1 below:

Analysis of the Factors Influencing Residential Domestic Water Consumption

The results of the OLS model run are mentioned below:

Y = 54.16 + 2.466 no_dependents +0.941 no_of_working_members + 1.755 location_zone1 +12.81location_zone2 +11.85location_zone3 +2.659 location_zone4+ 7.362 location_zone5 + 21.39 *location_zone7 +3.376 lnsizeofthehouse –9.239 others -3.156 knowledge_abt_price + 0.830 primary_higher_edu + 4.378 university_above_edu +e*

Where:

Y = Water Consumption

no_dependents = Number of Dependents

no_of_working_members= Number of Working Members

location_zone1 = South Zone

location_zone2 = East Zone

location_zone3 = West

location_zone4 = Bommanahalli

location_zone5 = Yelahanka

location_zone6 = RR Nagar (Reference Variable)

location_zone7 =Dasarahalli

lnsizeofhouse = Log of Size of the House

Others – This variable includes source of water (BWSSB or other source which can include private water sources such as private borewell and bottled water)

knowledge_abt_price = Knowledge about price of Water

primary_higher_edu = Primary and Higher Education Level

university_above_edu = University and Above Education Level

e = Error Term

Number of obs = 459
F (19, 437) = 34.02
Prob > F = 0.0000
R-squared = 0.307
Root MSE = 12.124

The above table denotes the summary of the regression model. The Prob >F at 0.00 signifies that the OLS fitted for the multiple regression model capturing the effect of various qualitative and quantitative independent variables on water consumption demand in the city of Bangalore is statistically highly significant at 1% confidence interval. The R- square value given at 0.307 denotes that 30.7% of the variations in the water consumption demand is being explained by the selected independent variables.

The OLS Model Result

VARIABLES	OLS Model
no_dependents	2.466*** (0.626)
no_of_working_members	0.941 (0.484)
location_zone1	1.755 (2.825)
location_zone2	12.81*** (2.559)
location_zone3	11.85*** (2.276)
location_zone4	2.659 (2.245)
location_zone5	7.362** (2.955)
location_zone7	21.39*** (2.724)
lnsizeofhouse	3.376** (1.709)
others	-9.239*** (2.017)
knowledge_abt_price	-3.156** (1.558)
primary_higher_edu	0.830 (1.588)
university_above_edu	4.378** (1.748)
Constant	54.16*** (13.05)
Observations	459
R-squared	0.307

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

For the above result to be more robust, some of the post estimation has been done. The results of the same are mentioned below:

By default, STATA assumes homoskedastic standard errors, so we need to adjust our model to account for heteroskedasticity. To do the same, 'robust' command is used while running the regression. This avoids the problem of homoscedastic standard errors.

An important assumption for the multiple regression model is that independent variables are *not perfectly multicollinear*. One regressor should not be a linear function of another. When multicollinearity is present, standard errors may be inflated.

To check multicollinearity, vif (variance inflation factor) command is used in STATA right after running the regression. The resulting table is mentioned below:

```
. vif
```

Variable	VIF	1/VIF
location_z~1	1.86	0.538745
location_z~4	1.57	0.638608
location_z~2	1.53	0.654360
location_z~5	1.36	0.734649
others	1.36	0.734915
location_z~7	1.36	0.736387
location_z~3	1.35	0.739746
no_depende~s	1.33	0.751282
lnsizeofho~e	1.23	0.812726
university~u	1.18	0.850906
primary_hi~u	1.15	0.869274
knowledge_~e	1.13	0.886403
no_of_work~s	1.12	0.895304
Mean VIF	1.35	

A vif > 10 or a 1/vif < 0.10 indicates trouble.

There seems to be no problem of multicollinearity in the model as well. Hence the above OLS model seems to estimate robust unbiased coefficients, thereby identifying the significant variables influencing residential water consumption in Bengaluru Urban.

Test for Normality

Skewness Kurtosis Test for Normality

Skewness is a measure of the asymmetry of the probability distribution of a random variable about its mean. It represents the amount and direction of skew. On the other hand, Kurtosis represents the height and sharpness of the central peak relative to that of a standard bell curve.

Null hypothesis – The data follows normal distribution.

Alternate hypothesis – The data does not follow normal distribution.

```
. sktest e
```

Skewness/Kurtosis tests for Normality

Variable	Pr(Skewness)	Pr(Kurtosis)	joint adj chi2(2)	joint Prob>chi2
e	0.380	0.114	3.27	0.1946

From the above table, the probability of skewness which is 0.380 is implying that skewness is asymptotically normally distributed (p-value of skewness > 0.05). Similarly, pr(kurtosis) which is 0.114 indicates that kurtosis is also asymptotically distributed (p-value of kurtosis > 0.05). Finally, adj chi(2) is 3.27 which is greater than 0.05 implying its significance at 5% level. Consequently, the null hypothesis cannot be rejected. Therefore, according to the skewness test for normality, residuals show normal distribution.

Model Specification Test

Model misspecification happens when the model does not account for everything it should. The probable reasons for the same could be when the regression has biased coefficients or error terms.

There are two tests which are available to test for the same: Ramsey Test and Link Test. The results of the two tests used in the current study are mentioned below:

Ramsey Test

The null hypothesis: The model does not have specification error.

```
. ovtest

Ramsey RESET test using powers of the fitted values of tn_water_cons
       Ho:  model has no omitted variables
                 F(3, 442) =       1.95
                   Prob > F =      0.1215
```

Since the p value is more than the threshold of 0.05 (95% significance), we fail to reject the null and conclude that the model is correctly specified.

LINK TEST

Another command to test model specification is linktest. It basically checks whether we need more variables in our model by running a new regression with the observed Y (ln water consumption) against Yhat (ln water consumption_predicted or Xβ) and Yhat-squared as independent variables. What we need to look for is the significance of _hatsq.

The null hypothesis is that there is no specification error.

The p-value of _hatsq is not significant, hence we fail to reject the null and conclude that our model is correctly specified.

```
. linktest

      Source |       SS       df       MS              Number of obs =     459
-------------+------------------------------           F(  2,   456) =  103.14
       Model |  42222.6658     2  21111.3329           Prob > F      =  0.0000
    Residual |  93338.1109   456  204.68884            R-squared     =  0.3115
-------------+------------------------------           Adj R-squared =  0.3084
       Total |  135560.777   458  295.984229           Root MSE      =  14.307

------------------------------------------------------------------------------
tn_water_c~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        _hat |   2.798218   1.070362     2.61   0.009      .6947648    4.901671
      _hatsq |  -.0096125   .0057094    -1.68   0.093     -.0208325    .0016075
       _cons |  -83.22421   49.86477    -1.67   0.096     -181.2175    14.76904
------------------------------------------------------------------------------
```

From the above model, it can be concluded that the factors which significantly influence water consumption in Bengaluru Urban are No of dependents, Location 2,3,6 and 7, Size of the House, private source of water, public source of water, private and public source of water, Knowledge about water price and Water Bill.

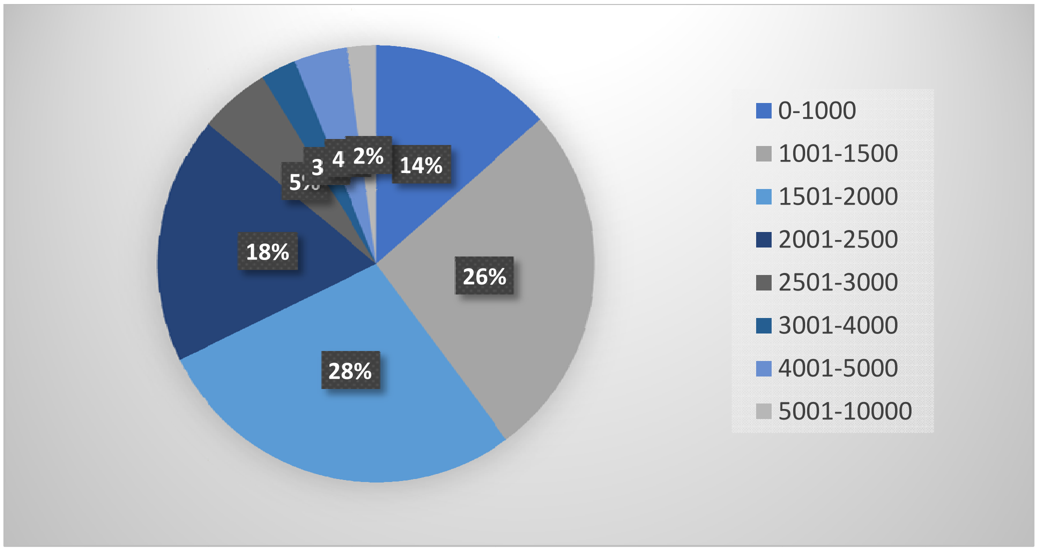
Analysis of the Significant Variables

Size of the House

From the above model, 'size of the house' variable is significantly influencing water consumption in Bengaluru Urban.

From the total 459 households surveyed, the chart below shows the break-up of the houses according to the square-feet categories.

Figure 2: Number of Houses Categorised according to Square Feet



Source: Author's calculation

From the chart above, it can be seen that the largest number of houses falls in the category of 1501-2000 square feet and the second largest falls in the category of 1001-1500 square feet. Both these categories account for more than 50 per cent of the sample, indicating that the majority of consumers fall in the category of middle income. Hence the policies which aim to achieve reduction in water consumption, must consider middle-income class households as an important category.

Number of Dependents

The variable **number of dependents** in the family is significant at 1% and has a positive slope. It denotes that a unit increase in the number of dependents in a household increases the water consumption by 2.466 units, keeping everything else constant.

Dependent age category consists of two bands – 0-14 yrs. of age and 60+ age category. From the data, the number of households with members in dependent age category is being shown in the table below:

Table 4.1: Number of Households with Members in Dependent Age Category

	1 member	2 member	3 member	4 member	more than 4 member	No members
0-14 age category	128	87	10	2	2	228
60+ category	73	96	15	6	2	265

Source: Author's Calculation

From the table above it can be identified that majority of households i.e. 128 households out of the total sample of 457 have one child below the age of 14 in their houses and 87 households have two children in the same category. More than half the sample size i.e. 228 households do not have any members who fall in the age category of 0-14 years. The increased consumption of water in such households with children is obvious due to inelastic demand.

Similarly, in the 60+ category, of the total sample of 457 households, 73 households have one member while 96 have 2 members in the household falling into the age category of 60+. Again, more than half the sample i.e. 265 households do not have any members falling in the age category of 60+.

Table 4.2: Households Consisting of Members in Both 0-14 Age Group and 60+ Age Group

No of households	0-14 age category	60+ category
18	1	1
18	2	1
23	1	2
26	2	2
1	3	1
3	1	3

Source: Author's Calculation

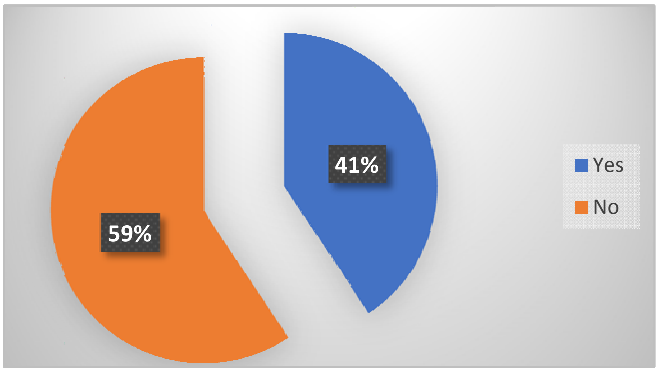
A further break-up of the analysis from the above table also shows that 26 households have 2 members falling in the 0-14 age category along with 2 members falling in the 60+ category. Followed by this, 23 households have one member falling in the 0-14 age category along with 2 members falling in the 60+ category.

Knowledge about the Price of Water

The **knowledge about the price of water**, which is determined in terms of presence or absence of knowledge, is significant at 5%, and has a negative slope implying an inverse relationship between them. It can be inferred that if the individual possesses knowledge about the price of water, then water consumption falls by 3.156 units.

If the objective is to bring about behavioural change among consumers, then it is important for consumers to be aware of the product they are consuming and its price. Literature suggests that having knowledge about the price of water brings a reduction in wasteful water usage and hence leads to efficient water consumption. The model above shows the variable to be significant. Of the total sample, surprisingly more than half of the sample were not aware about the per unit price of the water they were consuming. The chart below shows the percentage of households who responded with YES or NO when asked about whether they were aware of the per unit price of the water they consume:

Figure 3: Percentage of Household Responding to Knowledge about Per Unit Price of Water



Source: Author's calculation

It is surprising that 59 per cent of the households were not aware of the per unit price they pay for the water they use. BWSSB wants to ensure consumers demand less water, judiciously use the water and avoid wastage. How can they achieve this objective if the consumer has imperfect information? No doubt the board is spending on advertising about saving water, but it must be noted that a display board in one stationary position in the city will not achieve the objective. It is imperative the board adopts new technology in giving the consumers a nudge about the quantity and price of the water they consume. Sensors, digital water meters etc. are almost becoming obsolete in the technology space, yet water meters still remain those which can only display information useful for billing but not for creating consciousness in reducing wasteful water consumption.

Source of Water

In the variable source of water, public piped water source versus others category is included in the model. As mentioned above, the others category comprises all combinations of private water supply sources other than BWSSB piped water supply. The model shows the variable is significant at 1 % and the slope coefficient is given at -9.239, implying an inverse relationship between other sources of water and water consumption i.e if the source of water supply is other than public piped water supply, then water consumption falls. The reasoning for the same could be the higher price which the consumer pays for a private source relative to the public piped water source which brings in consciousness about water usage. For every litre of water the BWSSB supplies to a residential connection, it charges 0.04 paise. In the case of private water tankers, the average price they charge for a litre of water in Bengaluru Urban is 0.15 paise. Also, the effort taken to procure private water supply could also be a reason for the inverse relationship observed.

Easier the availability of fetching/getting water, the more the commodity is taken for granted while consuming it. The source of water variable in the model has been subdivided into the categories mentioned below in the table. From the table, it can be seen that a majority of consumers i.e. 334 households from the sample depend only on BWSSB piped water supply. Another observation is that 43 households depend only on private water tankers. As mentioned earlier, the prices charged by private water tankers are much higher than the BWSSB water charges. This induces the consumer to judiciously use the commodity. Apart from this, it can be seen that many households also depend on multiple sources apart from BWSSB water supply, highlighting the fact that BWSSB water supply is not sufficient for the household needs. It also highlights the fact that though for additionally sources of water the price is high, consumers still show a willingness to pay for the commodity. Hence the pricing becomes crucial to ensure judicious usage along with increased revenue to the board. But since water is a politically sensitive commodity, often it becomes a victim of wrong pricing and ultimately leads to acute shortage, especially during the summer season. The board must look at the option of peak period pricing to ensure the equity and sustainability of water availability.

Another interesting observation is that most of the households now possess private borewells. The electricity charge for running the motor for the borewell is accounted and charged, but why not the water which is pumped? It will not be fair to charge the consumers initially due to the heavy investment incurred for digging the borewell, but that cannot be the reason for not charging for the water at all. The board must fix a few initial years until the rate of return on investment is met. Consumers can enjoy free water for that period. But after that period, the borewell must be metered and water must be charged. This will avert the tragedy of the commons problem since underground water is a common resource available for all. By charging for the use of private borewell water, the board can also to an extent indirectly reduce the water theft by private water tankers from residential households who sell the water at a high price to the private tankers but end up paying no price at all for the water sold since private borewell water is free.

Table 5: Number of Households Categorised into Various Water Sources

Water Source	**No of Households**
Piped Water Supply	334
Private Borewell	7
Private Water Tankers	43
Piped Water Supply + Private Water Tanker	15
Piped Water Supply + Private Water Tanker +Private Borewell	18
Private Open Well	1
Public Borewell	5
Bottled Water	0
Piped Water Supply +Bottled Water	3
Others	5
Piped Water Supply +Pvt Open Well	8
Piped Water Supply +Pvt Borewell	20

Source: Author's Calculation

Location

Of the total sample considered for the study, the break-up according to the zones has been presented in the table below. RR Nagar Zone has been considered as a reference variable in the model. From the model, Zone 2 (East), 3 (West) 7 (Dasarahalli) and Zone 5 (Yelahanka) are significant. **Zone 2 (East), 3 (West) and 7 (Dasarahalli)** are significant at 1 per cent while Location 5 (Yelahanka) is significant at 5 per cent. The sign of all the coefficients are positive, implying if the sample belongs to either zone 2, 3, 5 or 7, the water consumption increases as against the base category which is zone 6 (RR Nagar). For inequity in water distribution to be assessed and also to identify wasteful usage of water, it becomes imperative to identify from which zones the water consumption is highly inelastic.

Table 6: Zone Wise Break-up of the Total Sample

Zones	Number of Households Surveyed
Dasarahalli	61
East	96
RR Nagar	42
South	75
Bommanahalli	39
West	75
Yelahanka	39

Source: Author's Calculation

Education

Variable **education** is divided into two categories – **primary and higher education** as one variable and **university and above** education as another variable. Of the two variables in the model, university and above variable is significant at 5 per cent with a coefficient of 4.37, implying that if the household has a member with an education level of university or above, then the water consumption increases by 4.378 units. The reasoning for the same could be that increased education increases the probability of securing a high-paying job and hence the proportion of income spent on water will become less, thereby reducing the consciousness of water conservation and efficient water usage. Of the sampled households, 364 households comprised members whose education level was a university degree and above.

Conclusion

The following conclusions can be made from the study:

- The total households surveyed was 500 and after cleaning the data, 459 were considered in the OLS model to identify the significant variables affecting water consumption.
- The overall model after testing for Gauss Markov assumptions proved to explain that 31 per cent of the variations in residential public water consumption were affected by the selected significant variables.

- OLS model identified No of dependents, Location (East, West, Yelahanka and Dasarahalli), Size of the House, Other source of water other than piped public water supply, Knowledge about water price and University and above education variable to be the significant variables affecting water consumption in Bengaluru Urban.
- Of the above-mentioned variables, No of Dependents, Location (East, West and Dasarahalli) and Other source of water other than piped public water proved to be significant at 1%.
- Variables Location Yelahanka, Size of the House, Knowledge about water price and University and above education variables were significant at 5%.

In conclusion, the paper draws light upon the factors which significantly affect residential water consumption in Bengaluru Urban district. Often, the focus of the urban local body responsible for supplying piped water to Bengaluru residents (BWSSB) is on expanding the infrastructure necessary for increasing the water supply. However, a key point observed is that a majority of the resources for this infrastructural increase come in the form of loans and assistance from the state government and also international collaborations. This form of resource often tends to be unsustainable if the revenue from water tariff is not sufficient to cover the costs. While fixing water tariff, the BWSSB needs to ensure that at least the marginal cost of providing water is recovered. To achieve this, apart from the price factor alone, the BWSSB needs to focus on other significant variables which influence water consumption as highlighted in the study. Hence fixing the correct water tariff even under the IBT system must be backed by scientific reasoning and must consider all crucial factors influencing water consumption. Secondly, awareness about water pricing will influence water consumption as identified in the study. If the BWSSB intends to conserve water by reducing water demand, then it becomes important to create awareness about the price of water that the consumer consumes. As identified in the study, more than 50 per cent of the consumers were unware of the per unit price of the water they pay. Awareness about water scarcity and hence water conservation must be given focus by the BWSSB which has ignored it in its efforts to tide over the water crisis in the city. Thirdly, to reduce the inequity in water supply, BWSSB must make an attempt to identify which of the zones or even BBMP wards consume less water compared to the stipulated norm and what is the reason for it. Hence a monthly chart showing the water consumed in lpcd by BBMP wards can be calculated and also tracked monthly so that targeted action can be taken on such wards which receive very little water. On a macro perspective, it is imperative to move towards an integrated water management system if the water situation in Bengaluru city is to become reliable, equitable and sustainable.

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